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(54) Shoe with spring-like sole member.

(57) A shoe, which is adapted for a particular type of activity, such as running, is provided with a flexible resilient member interposed between an outer sole and an inner sole for storing and releasing energy during each running step. The flexible resilient member is arranged to flex in the region of the ball of the foot of the wearer. whereby as the foot is flexed, energy is stored in the flexible resilient member, and as the foot leaves the ground, the flexible resilient member restores itself to its resting condition while releasing the stored energy in a manner which assists the running motion of the wearer,. The flexible resilient member may be formed of a fiber reinforced polymeric material, such as carbon fiber reinforced epoxy which has a directional flexure characteristic. A plurality of such directional layers of the material may be bonded to one another, so as to achieve a desired overall flexure characteristic which may have different longitudinal and transverse components. The flexure characteristic may be adapted for various wearer weights and running styles, as well as for characteristics of running surfaces.

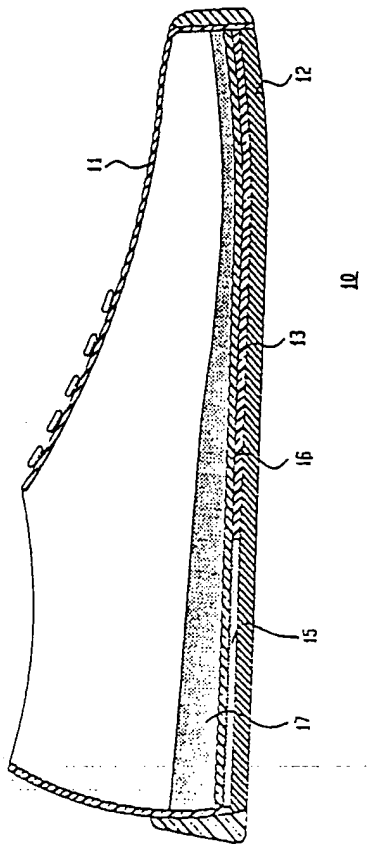

FIG. 1

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SHOE WITH SPRING-LIKE SOLE MEMBER

Background of the Invention

This invention relates generally to footwear, and more particularly, to a shoe having incorporated therein a leaf spring-like member which is formed of a fiber-reinforced polymeric material for absorbing and releasing energy during each step.

A variety of approaches have been taken in the prior art toward relieving the stresses which are imposed on a human foot during walking and running. One well known approach utilizes resilient, spring-like arrangements which absorb and release energy during each step of walking or running. The known arrangements store and release energy via resilient members which generally are arranged to operate in a direction which is generally orthogonal to the sole of the shoe so as to absorb and redistribute localized loads and forces.

U.S. Patent No. 4,492,046 describes a running shoe which has a spring wire arrangement disposed in a longitudinal slot in the sole. The spring wire is arranged to urge the slot open apparently so that as the heel of the wearer comes downward, the slot is closed, and as the weight of the runner shifts forward onto the metatarsal heads, or ball, of the foot, the spring urges the upper section of the sole away from the lower section so as to assist in the weight shift. Such assistance is stated in the patent reference as launching the runner into a comfortable stride. Clearly, this known arrangement is complex, heavy, and probably dangerous in that the heel end of the bottom of the shoe may cause the runner to trip and fall.

A further known spring-action running shoe is described in U.S. Patent No. 4,534,124 which shows an athletic shoe coupled at its toe end to a leaf spring; the leaf spring being coupled at its rearward end to a further, lower sole. As described in this reference, the running shoe proper is arranged parallel and at some distance with respect to the lower sole such that any weight being applied to the running shoe would result in a storage of energy in the leaf spring. Clearly, such a structure is heavy, bulky, complicated, and accident-prone.

It is, therefore, an object of this invention to provide a simple and economical shoe having associated therewith an arrangement for storing and releasing energy in a manner beneficial to a runner.

It is another object of this invention to provide an arrangement which stores and releases energy in conformance with the natural foot movement of a runner.

It is a further object of this invention to provide a running shoe having an arrangement where energy stored during each running step is released in a direction of travel of the runner.

It is also an object of this invention to provide a resilient leaf spring-like member for incorporation in a shoe, the spring-like member having a lifetime of many flexures.

It is an additional object of this invention to provide a resilient spring-like member which cooperates with a shoe so as to have a flexure characteristic which is easily adaptable for a particular runner.

It is still another object of this invention to provide a resilient spring-like member for incorporation in a shoe so as to have a resilient characteristic which is easily adaptable to complement the resilience characteristic of a running surface.

It is a still further object of this invention to provide a resilient spring-like member which can easily be incorporated in a running shoe.

Summary of the Invention

The foregoing and other objects are achieved by this invention which provides a shoes having a leaf spring-like flexible resilient member arranged in the vicinity of the sole of the shoe. In accordance with the invention, the flexible resilient member has a predetermined flexure characteristic and is arranged to flex with the sole of the shoe, in the region of the ball of the foot of the human wearer, during each step. In this manner, the material, which may be a fiber-reinforced polymeric material, stores and releases energy in response to such flexure during each step.

In one embodiment of the invention, the material which forms the flexible resilient member may be a carbon fiber reinforced epoxy which is formed of a plurality of layers. The configuration and thickness of each layer, as well as the number of such layers can be selected to form the predetermined flexure characteristic. In this manner, the flexible resilient member is adapted to the weight and other characteristics of the wearer. In one embodiment, the various layers are bonded to one another. Additionally, the entire flexible resilient member may be interposed between an outer sole of the shoe and an inner sole thereof which communicates with the foot of the wearer.

Each layer of fiber-reinforced polymeric material may have a flexure characteristic which is directional resulting from the orientation of the reinforcing fibers within the material. Typically, such

material can withstand greater forces, such as bending forces, in the direction of the fiber orientation, than transverse thereto. In one embodiment of the invention, the various layers of fiber-reinforced material which form the flexible resilient member may each have a directional aspect to the flexure characteristic. Such layers may be arranged so that the directions of the fiber orientation are at respective angles to one another. In this manner, the longitudinal and transverse flexure characteristics of the flexible resilient member can be tailored for a specific activity in which the human wearer is expected to engage. In a specific illustrative embodiment, the layers are arranged such that the fiber orientation of some of the layers is longitudinal with the shoe, while other such layers are at 45° to either side thereof. For most applications, the flexible resilient member will be stiffer in the longitudinal direction. As indicated, the stiffness of the flexible resilient member can be tailored to specific applications by varying the number of layers of fiber-reinforced material, as well as the angular orientations of the layers. Clearly, the particular flexure characteristic to be incorporated in any given shoe should be tailored to the weight of the wearer, the running style of the wearer, the nature of the particular activity in which the wearer is expected to engage, and the characteristics of the surface on which such activity will take place. A heavy runner will require a fairly stiff flexible resilient member, and therefore the flexible resilient member of a shoe tailored for such a runner would be formed with a greater number of layers of carbon fiber material, irrespective of shoe size. Additionally, sprinters will require stiffer flexible resilient members than marathon runners, since sprinting imposes greater forces and inertial loads on the foot of the runner than slower running, such as marathon running. Football players, who generally are heavy athletes and are required to sprint, would require relatively stiff resilient members in their shoes.

The present invention is premised at least partially on the recognition by the inventor herein that the achievement of effectual energy return for a runner, sufficient to improve the performance of the wearer in a given activity, requires shoes having incorporated therein resilient, spring-like members which are significantly stiffer, or more resistant to flexing, than conventional athletic shoes. This understanding requires acceptance of a premise which is entirely contrary to the approach accepted by present day shoe designers and manufacturers.

The generally accepted view is that the speed and comfort of a runner is improved by using light and flexible footwear. This view is apparently deemed in the present state of the art to be mandated by classical mechanics which assumes that reduction in the force required to flex the footwear during use of the shoe, and reduction in the mass of the footwear, will result ultimately in the reduction of total energy required to be exerted by the user of the footwear, and thereby induce improvement in runner speed and endurance.

In accordance with a practical embodiment of the invention, the flexible resilient member is formed of plural layers of carbon fiber material which may be cast in a solidifying material, such as epoxy. In a running shoe, where only moderate lateral, or transverse, loads are encountered, it is desired to achieve a significant longitudinal stiffness, substantially along the axis of the foot, which stiffness operates to resist, in a spring-like manner, flexure of the shoe in the vicinity of the metatarsal heads of the foot.

It is desired, in a running shoe embodiment of the invention, to minimize transverse stiffness. Although significant amounts of transverse stiffness can be avoided by aligning the fibers of the carbon layers longitudinally with respect to the foot of the user, the resulting absence of transverse support will permit the epoxy of the casting to fracture in a direction along the carbon fibers. Thus, in a practical embodiment a compromise is achieved by orienting the carbon fiber layers at predetermined angles with respect to one another, whereby they layers are arranged at offsets corresponding to rotations of approximately 10° from the longitudinal axis.

In a highly advantageous embodiment, particularly with respect to shoes in the range of men's sizes 8 to 12, the resilient spring-like member is formed of four layers of carbon fiber material. The first layer is arranged so that its aligned carbon fibers are disposed at a 10° counter clockwise orientation (+10°) with respect to the longitudinal axis, and the second layer is arranged at a 10° clockwise orientation (-10°). In order to achieve symmetry, and thereby avoid deformation during setting of the potting epoxy in the mold, the third and fourth layers are arranged at -10° and +10°, respectively.

A shoe constructed using the flexible resilient member described hereinabove is thus tuned, in the sense of energy storage and return, within a range which would achieve the advantages of the present invention for a broad segment of the population. As previously indicated, the tuning of shoes for specific individuals can be achieved in a variety of ways, including using different numbers of carbon fiber layers in the resilient member. For example, for sizes 4 to 8, two or three carbon fiber layers may be used.

The shoe of the present invention is not as flexible as conventional running shoes. Moreover, certain embodiments of the inventive shoe may be

heavier than conventional shoes. Thus, the advantages of the present invention are achieved in a manner which seems contrary to the current thinking of those skilled in the art of shoe manufacture.

As previously noted, transverse stiffness may not be desirable in running shoes. Substantial transverse stiffness will exaggerate the wearer's tendency toward pronation, which is manifest as a rapid medial shift in the center of pressure immediately after the heel strikes the ground during running. There are, however, activities such as tennis or basketball which require the participant to apply high transverse loads, particularly during rapid changes in direction. In accordance with the invention, shoes constructed for these types of activities are preferably provided with significant lateral stiffness, which can be achieved by increasing the angles of orientation of the aligned carbon fibers from approximately ±10° to ±90°.

In some embodiments, the flexible resilient member will be generally planar and extend only throughout the foremost two-thirds of the shoe. The heel portion of such a shoe could be provided with a cushioning material which will absorb and redistribute shock forces and loads. In other embodiments, however, the flexible resilient member extends throughout the length of the shoe and can serve the same function at the heel of the shoe as described hereinabove for flexure in the region of the metatarsal heads of the foot of the wearer. In addition, the flexible resilient member need not be entirely planar, and instead may be curved in a manner which conforms to the sole of the shoe. For example, the flexible resilient member may be curved upward in the region of the front of the shoe.

In embodiments of the invention where the flexible resilient member does not extend for the entire length of the shoe, the rear portion of the shoe may be provided with a spacer formed of a resilient damping material. Such a spacer may be formed of a cushioning material, including a commercially available force distributing material marketed under the trade name Sorbothane. When subjected to a shock-type load, this material functions somewhat as a liquid in that it distributes the load throughout itself. This has the effect of reducing the overall shock force experienced by any given point in the region of the heel of the foot of the wearer of the inventive shoe.

In other embodiments of the invention, an inner sole is provided to prevent communication of the foot of the wearer directly with the flexible member. Such direct communication could result in bruising or other injury to the foot of the wearer, particularly in the region of the metatarsal heads. Elimination or reduction of this type of injury can result in significant improvement in the wearer's athletic performance. In addition, certain embodiments of the invention may be provided with a metatarsal pad which is located on the inner sole in a region thereof which corresponds to a location immediately behind the metatarsal heads of the foot of the wearer. Such a metatarsal pad has the effect of lifting the foot slightly so as to ease the load on the metatarsal heads. This, of course, can reduce fatigue and improve performance. In addition to the foregoing, the inner sole may be provided with a metatarsal cushion located immediately beneath the metatarsal heads. Such a cushion would serve to distribute more evenly the forces applied to the metatarsal heads.

In accordance with a further aspect of the invention. the flexible resilient member cooperates with the outer sole and the heel of the shoe to achieve a tuned response. Thus, the flexible resilient member functions as a spring, while the outer sole and heel operate as a damping medium. In addition, the inner sole can also function as a damping medium. The damping media may assist in reducing one or more oscillation modes of the shock wave produced in a runner's leg by the impact at foot-strike and also may assist in tuning the system for the particular running characteristics of the wearer. Similarly, in embodiments of the invention where the flexible resilient member extends to the rear of the shoe so as to provide its advantageous effect in the heel region, cushioning material in this region can served to dampen oscillations as described hereinabove.

Brief Description of the Drawing

Comprehension of the invention is facilitated by reading the following detailed description in conjunction with the annexed drawing, in which:

FIG. is a cross-sectional representation of a shoe constructed in accordance with the invention;

FIG. 2 is a cross-sectional representation of a further embodiment of the invention wherein various structural components are removable;

FIG. 3 and 4 are cross-sectional side, and plan top, views of an insole embodiment suitable for use with the invention; and

FIG. 5 is a cross-sectional representation of a shoe constructed in accordance with the invention having a curved flexible resilient member and the insole of FIG. 4.

Detailed Description

FIG. 1 is a cross-sectional representation of a shoe 10 constructed in accordance with the invention. As shown, shoe 10 has an upper portion 11

which may be constructed in a manner which is known in the art. The shoe has an outer sole 12 which, in this embodiment, serves as the outermost bottom layer. A flexible resilient member 13 is arranged to communicate with outer sole 12 and extends throughout the front portion of the shoe. In the rear portion of the shoe however, a cushion spacer 15 communicates with the outer sole and serves to dampen and distribute shock forces which are created when the heel portion of the shoe is urged into communication with the ground (not shown) during running. In addition, cushion spacer 15 serves to retain the flexible resilient member in place and avoid its shifting backward.

The flexible resilient member and the cushion spacer are covered, in this embodiment, by an insole 16. In addition, this embodiment is provided with a soft cushion layer 17. The insole and the cushion layer serve to provide comfort to the wearer, while also protecting the foot of the wearer from direct communication with the flexible resilient member. In this specific embodiment, cushion layer 17 is provided with additional thickness in the vicinity of the heel portion of the shoe. This extra thickness provides an additional cushioning support which reduced transmission of peak forces during running to the heel of the wearer.

FIG. 2 is a cross-sectional representation of a shoe 20 constructed in accordance with the invention so as to have removable components. This shoe has an upper portion 21 which may be of conventional construction. Additionally, the shoe is provided with an outer sole 22 and a flexible resilient member 23. However, in this embodiment, an inner sole 24 is in direct communication with outer sole 22 and is interposed between the outer sole and the flexible resilient member. A cushion spacer 25 is provided in the heel region of the shoe. However, unlike the embodiment of FIG. 1, the cushion spacer and the flexible resillent member in the embodiment of FIG. 2 are removable. When thus removed, shoe 20 can be used as a conventional shoe, with the foot of the wearer communicating directly with insole 24. Cushion spacer 25 is shown to couple with the flexible resilient member. Any of several known coupling arrangements can be used to insure that the cushion spacer and the flexible resilient member maintain their positions with respect to one another. In this specific embodiment, a soft cushion insole 27 is provided on top of the flexible resilient member and the cushion spacer. Of course, cushion layer 27 is removable, thereby permitting access to the removable flexible resilient member and cushion spacer.

FIGS. 3 and 4 are side and top plan views of an illustrative embodiment of a cushion insole 30 which is suitable for use with the shoe embodiments of FIGS. 1 and 2. Cushion insole 30 can be formed in a conventional manner. However, in this embodiment there is provided a metatarsal pad 32 which is arranged on the cushion insole in a region thereof corresponding to a position immediately behind the metatarsal heads of the foot of the wearer. In addition, the cushion insole is provided with a metatarsal cushion 33 which is located so as to communicate with the metatarsal heads of the foot of the wearer. In this embodiment, metatarsal cushion 33 is of the same thickness as the rest of the cushion insole.

FIG. 5 is a cross-sectional representation of a shoe 50 constructed in accordance with the invention and utilizing the insole described hereinabove with respect to FIGS. 3 and 4. This embodiment of the invention has an outer sole 52, immediately above which is arranged a flexible resilient member 53. In this embodiment, the flexible resilient member extends for only a portion of the length of the shoe, there being provided a cushion spacer 55 which operates in the manner described hereinabove with respect to the cushion spacers of FIGS. 1 and 2. The cushion spacer may be formed of a viscous material which cushions the heel and also serves to dampen oscillations of the flexible resilient member. Alternately, the flexible resillent member can extend to the rear of shoe 50, thereby obviating the need for cushion spacer 55. In such an embodiment, outer sole 52, and possibly an inner sole 56 all cooperate with the foot of the wearer to dampen any oscillations in the flexible resillent member.

In this specific embodiment, flexible resilient member 53 has a predetermined curvature which can add a measure of comfort to the wearer.

This embodiment of the invention utilizes a removable cushion insert 30, as described hereinabove with respect to Figs. 3 and 4. As shown in FIG. 5, cushion insole 30 conforms to the curvature of the shoe.

Although the invention has been described in terms of specific embodiments and applications, persons skilled in the art can, in light of this teaching, generate additional embodiments without exceeding the scope or departing form the spirit of the claimed invention. Accordingly it is to be understood that the drawing and description in this disclosure are proffered to facilitate comprehension of the invention and should not be construed to limit the scope thereof.

Claims

1. A shoe of the type worn on the foot of a human being for performing a predeterminable activity on a surface, the shoe comprising:

flexible outer sole means for communicating with the surface; and

flexible resilient means having a predetermined spring-like flexure characteristic and arranged in the interior of the shoe with respect to said flexible outer sole means, said flexible resilient means and said flexible outer sole means being arranged to flex together in response to flexure of the foot of the human being during a step of the predeterminable activity substantially in the region of the ball of the foot of the human being, whereby energy supplied by the human being is stored in said flexible resilient means in response to said flexure during each such step and released as said foot of the human being is lifted from the surface, said energy released from said flexible resilient means being returned to the human being in the form of a force having a magnitude characteristic applied to the human being over a time period said magnitude and said time period being responsive to said predetermined flexure characteristic of said flexible resilient means.

2. The shoe of claim 1 wherein said flexible resilient means comprises a layer of carbon fiber reinforced epoxy material.

3. The shoe of claim 2 wherein said carbon fiber reinforced material comprises a layer of carbon fiber material cast within an epoxy material, said layer of carbon fiber material having carbon fibers arranged in substantial alignment therein, there being further provided at least a further layer of said carbon fiber material cast within said epoxy material, said carbon fibers of said layers being arranged at predetermined angles of orientation with respect to one another and to a longitudinal axis of the shoe, to achieve said predetermined flexure characteristic.

4. In a shoe for the foot of a human wearer, a flexible resilient member disposed in the vicinity of the sole of the shoe and arranged to flex in response to flexure of the foot during performance of an activity on a surface, said flexible resilient member being formed of at least a first layer of fiber reinforced material and adapted to store energy in response to flexure of the foot during performance of the activity by the human wearer, and release said energy to the human wearer upon relaxation of said flexure in the form of a force applied to the foot of the human wearer by said flexible resilient member in accordance with a predetermined characteristic.

5. The shoe of claim 4 wherein said fiber reinforced material is reinforced with carbon fiber.

6. The shoe of claim 4 wherein said first layer of said fiber reinforced material is reinforced in a first direction to produce a predetermined flexure characteristic having a directional aspect.

7. The shoe of claim 6 wherein there is provided a second layer of said fiber reinforced material arranged to cooperate with said first layer and having a respective predetermined directional flexure characteristic, said directional characteristics of said first and second layers being arranged at a predetermined angle with respect to each other, so as to produce a predeterminable mid-flexure characteristic having selectable, longitudinal and transverse aspects.

8. The shoe of claim 7 wherein said predeterminable mid-flexure characteristic is selected in response to a characteristic of a wearer.

9. The shoe of claim 8 wherein said predeterminable mid-flexure characteristic is selected in response to a type of activity in which said wearer is expected to engage.

10. The shoe of claim 4 wherein there is further provided metatarsal support means arranged to relieve weight pressure on the metatarsal heads of the foot of the wearer.

11. A shoe for use on the foot of a human wearer, the shoe being of the type having a forward portion and a rearward portion, the shoe comprising:

outer sole means arranged on the bottom of the shoe: and

a spring-like member substantially in the form of a sheet of a fiber reinforced material, said spring-like member being arranged to be inward of said outer sole means and substantially parallel to said outer sole means so as to flex therewith and having a predetermined flexure characteristic in the region of the metatarsal heads of the foot of the human wearer.

FIG. 1

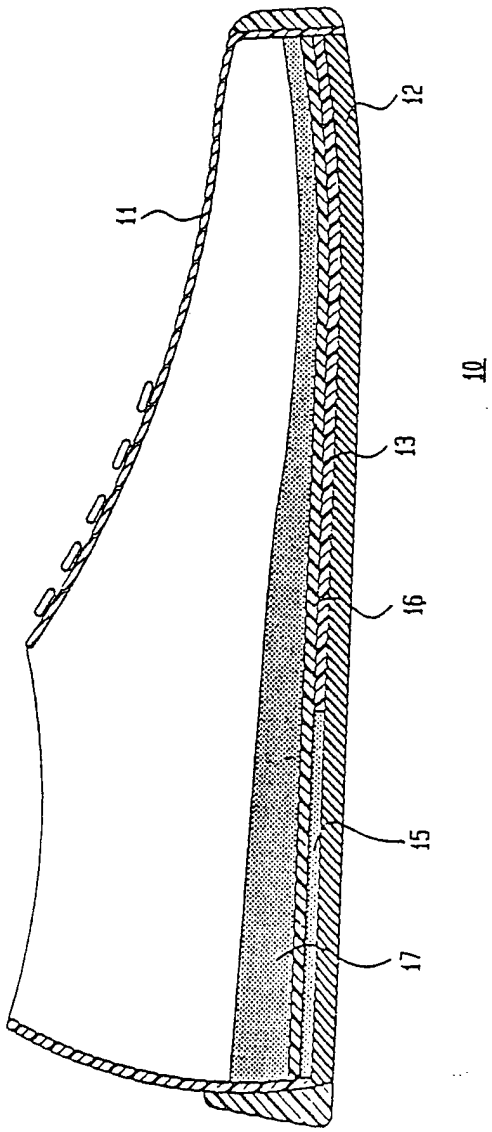
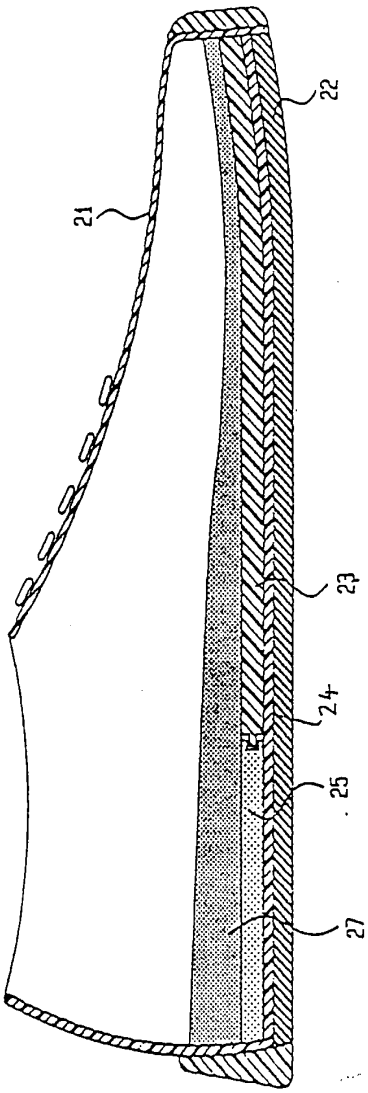


FIG. 2



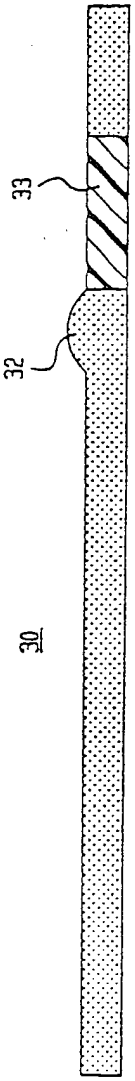


FIG. 3

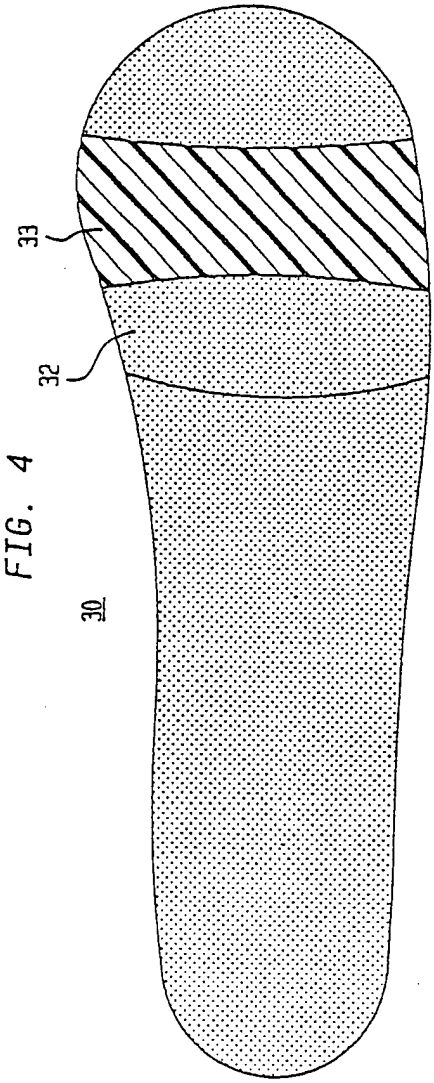


FIG. 4

FIG. 5